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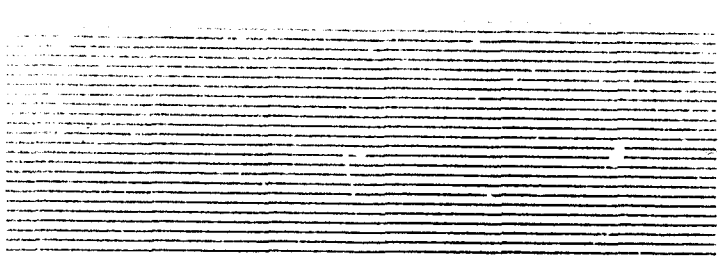

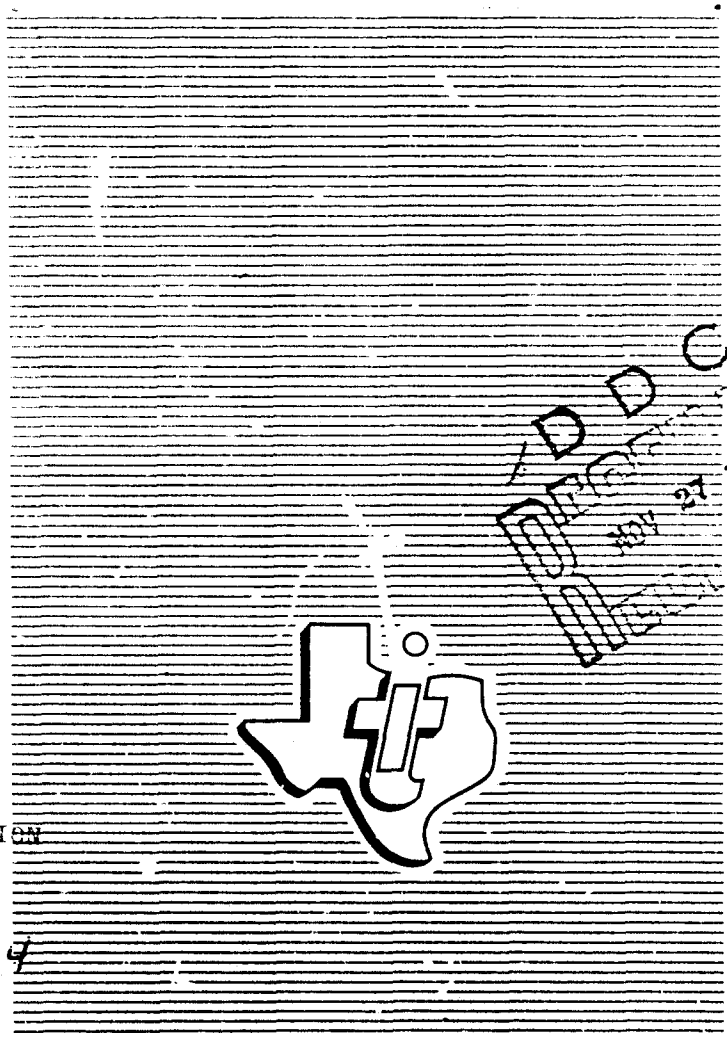





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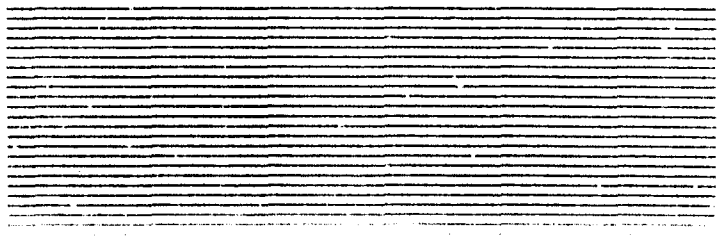

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# FINAL ENGINEERING REPORT
# FOR THE
# AN/APS-116(XN-3) RADAR SET
# 1970 - NOVEMBER 1972

2 NOVEMBER 1972 DR72-00-09

Prepared for:

NAVAL AIR SYSTEMS COMMAND
Washington, D.C. 20360

Contract N00019-70-C-0398

Data Item 11 of DD 1423

Prepared by:

Equipment Group
Search and USW Product
Customer Center
FSCM 96214

Texas Instruments
Part No. 720000-4

NASC Specification
MIL-R-81648(AS)



Approved by:

B.J. Ehrler, Program Manager
AN/APS-116(XN-3) Radar Set

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Declassify on 31 Dec. [redacted]
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NATIONAL SECURITY INFORMATION
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FINAL ENGINEERING REPORT
AN/APS-116(XN-3) RADAR SET
CONTRACT N00019-70-C-0398

## I. PURPOSE

(U) Contract N00019-70-C-0398 was awarded to Texas Instruments on 20 March 1970 to design, develop, manufacture, test and deliver AN/APS-116(XN-3) radar equipment in accordance with the requirements of MIL-R-81648(AS).

### A. Description

(C) Radar Set AN/APS-116(XN-3) is used for search and undersea warfare applications. Its primary purpose is to aid in submarine detection. The radar set employs high-resolution (pulse compression) techniques to achieve the capability of detecting submarine periscopes within five seconds after exposure under severe sea conditions at ranges of up to 20 miles. The radar set will detect submarine snorkles and may also be used for surface plotting, radar navigation, and station keeping. Refer to Table 1 for system operating parameters. A detailed description of the radar equipment is given in Paragraph III of this report.

### (U) B. Major Program Milestones

| EVENT | |
|---|---|
| Design and development work commenced | 1 Oct 1969 |
| Letter contract awarded | 20 Mar 1970 |
| Definitive contract awarded | 30 Apr 1970 |
| Design review conducted at TI | 16 Jun 1970 |
| Engineering model drawing release completed | 15 Sep 1970 |
| Engineering model assembly completed | 21 Dec 1970 |
| First preproduction unit assembly completed | 12 Feb 1971 |
| Last preproduction unit assembly delivered | 24 Apr 1972 |

(C) TABLE 1. PRINCIPAL SYSTEM OPERATING PARAMETERS (U)

| Parameter | Characteristics |
|---|---|
| Transmit frequency | 9.5 to 10.0 GHz |
| Peak Power | 500 KW |
| Pulse energy | 0.22 watt-second |
| Pulse width | 0.5 microsecond |
| PRF | |
| Mode I | 2000 PPS |
| Modes II and III | 500 PPS |
| Receiver sensitivity | |
| Modes I and III | 90 to 92 dBm |
| Mode II | 93 dBm (tangential) |
| Compressed video 3 dB pulsewidth | 3 nanoseconds |
| Antenna scan speed | |
| Fast Scan | 300 °/min |
| Slow Scan | 6 °/min |
| Primary radar inputs | |
| Primary power | 115 VAC, 3 phase, 400 Hz, 15 amps/phase |
| Pressurization | Freon 11C to pressurize waveguide to 30 psia |
| Cooling | Forced air |

## II. GENERAL FACTUAL DATA

### A. AN/APS-116(XN-3) Qualification Tests

(U) Qualification tests were performed to demonstrate the environmental capabilities of the AN/APS-116(XN-3) radar as required by Military Specification MIL-R-81648(AS). Each of the tests was conducted in accordance with the military approved procedure for the respective environment.

(U) The following tests were performed to satisfy the qualification requirements of the AN/APS-116(XN-3) radar. Refer to Paragraph III for a detailed description and the results of the tests.

Pre-qualification Reliability Burn-in Test

Reliability Qualification Test

Thermal Performance Test

Temperature/Altitude Test

Vibration Test

Humidity Test

Explosion Test

Salt Spray Test

Electromagnetic Interference Test

### B. Technical and Operational Evaluation

Technical evaluation (TECHEVAL) and operational evaluation (OPEVAL) of the AN/APS-116(XN-3) radar under actual flight conditions was performed by Naval personnel under authorization by the CNO. Refer to Paragraph III-E for a summary of results of the evaluation.

## III. DETAILED FACTUAL DATA

### A. System Equipment Description

(U) The AN/APS-116(XN-3) is basically a four WRA unit configuration consisting of a Synchronizer-Exciter, Receiver-Pulse Compressor, Transmitter and Power Supply. The system is designed for integration with other components to become a part of the S-3A Radar system.

(U) The relationship of the WRAs (as used in the OPEVAL/TECHEVAL radar set configuration) is illustrated in Figure 1.

(U) The Power Supply provides the antenna with servo drive signals, transfers control signals, provides primary power to other WRAs, and provides BITE information to indicate system readiness. The Synchronizer-Exciter provides radar set timing and synchronization, transmitter RF drive, and receiver LO drive. The Transmitter amplifies the Exciter RF energy and delivers it through a high-power circulator in the Receiver-Pulse Compressor to the Antenna for radiation. The Receiver-Pulse Compressor processes the returned RF pulses and provides video signals to an interface unit.

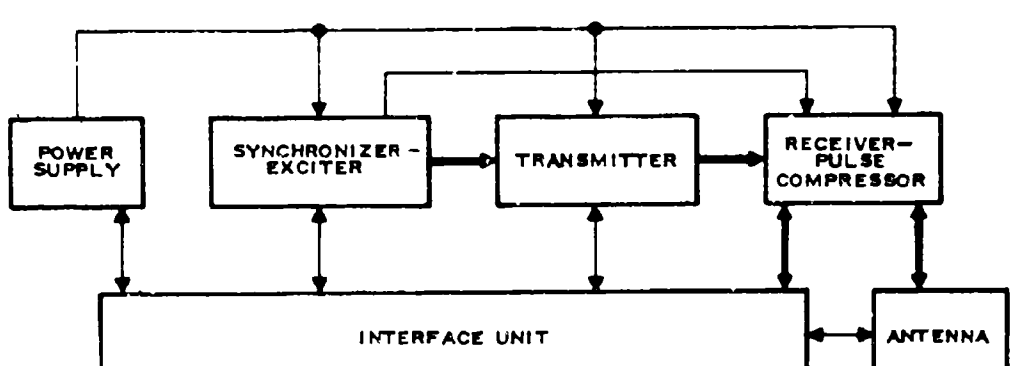


Figure 1-2. Opeval/Techeval Radar Set, Part Number 720000-1, Simplified Functional Block Diagram (U)

B. WRA Descriptions

(U) The WRA design is functionally modularized; therefore, the most practical repair method is by module replacement. This method is used to make full use of intermediate maintenance level facilities, eliminate where possible the need for complex test setups, and to minimize WRA repair time while minimizing the required amount of maintenance resources. The following paragraphs describe the physical and functional characteristics of each WRA.

(1) Power Supply PP-6633(XN-3)/APS-116(XN-3)

(U) The Power Supply (Figure 2) uses 400 Hz power to provide regulated and unregulated voltages to the other radar set WRAs. The rear panel contains three electrical connectors that route all signals to and from other WRAs, and one connector for test. The front panel contains an elapsed time indicator, fail indicator, and a BITE reset pushbutton switch. The FAIL indicator actuates if a failure is detected in the power supply. The reset switch resets the built-in test circuits and resets the FAIL indicators on the Exciter, XMTR, RCVR-PC and Power Supply. Heat dissipation is 360 watts and cooling is by cold plate.

(U) The Power Supply provides servo drive signals to the Antenna for scanning in all modes. No interface adjustments are required between the power supply and other WRAs. There are sufficient test points to an external connector to fault isolate malfunctions down to one of the 18 shop replaceable assemblies (SRAs). All SRAs are removable from the top of the unit.

(2) Synchronizer-Exciter SN-460(XN-3)/APS-116(XN-3)

(U) The Exciter WRA (Figure 3) consists of 30 SRAs, 13 of which are plug-in units that are removable from the top of the unit. The remaining SRAs are accessible from the sides, and are mounted on cold walls. The packaging concept of the Exciter is designed around cold-plate cooling and maintainability requirements. The unit basically consists of two cold plates mounted in a wraparound chassis with a printed wiring board (PWB) mounting tray in the center. The cold plates act as mounting surfaces for the modular subassemblies on the sides of the unit and as a radio frequency interference (RFI) shield between the modular sub-

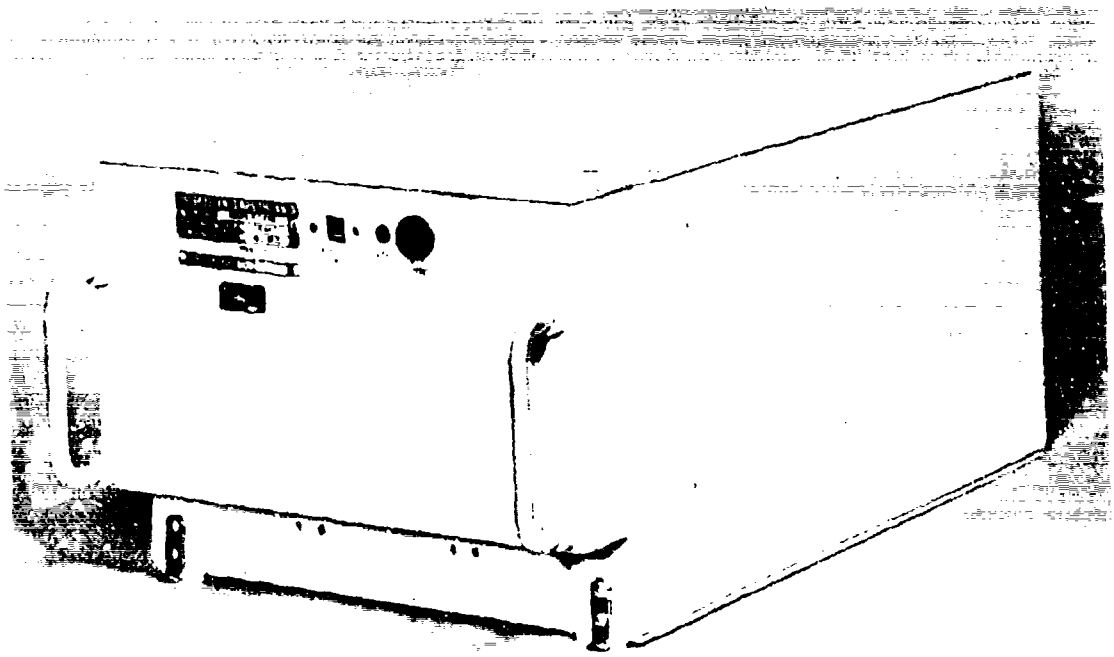

FIGURE 2. POWER SUPPLY PP-6630(XN-3)/APS-116(XN-3)

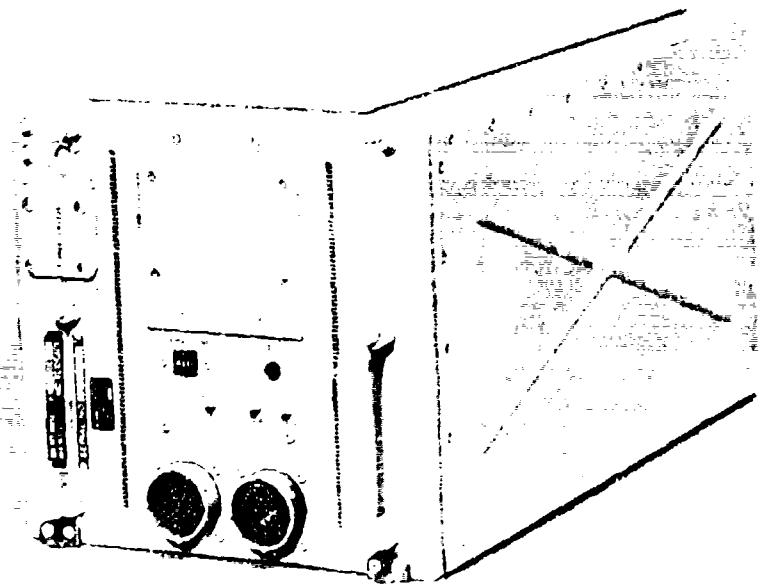

FIGURE 3. SYNCHRONIZER-EXCITER SN-460(XN-3)/APS-116(XN-3)

assemblies and the PWBs. Cooling air inters the cold walls at the front of the unit through two vertical slots. Cooling air is gathered at the rear of the unit in a plenum and exhausted through a single opening. All electrical connectors are located on the front panel. A front panel dust cover exposes the only organizational maintenance adjustment. This interface adjustment is accomplished if either the Exciter or RCVR-PC is replaced. Five SRAs require marriage adjustments if replaced.

(C) The exciter provides a 1 watt peak power, linear FM chirp, 0.8 μsec, 600 MHz bandwidth pulse of energy to the transmitter in Modes I and III; a 1 watt peak power, 0.8 μsec, 300 MHz agile bandwidth pulse of energy to the transmitter in Mode II; first and second system local oscillator frequencies; PRF generation and IFF synchronization; all radar set triggers and gates; and an RF test pulse to the Receiver.

(3) Transmitter, Radar Set T-1203(XN-3)/APS-116(XN-3)

(C) The transmitter (Figure 4) amplifies the low level RF pulse from the exciter. This 1 watt RF input pulse is reduced to 200 milliwatts with an attenuator before being amplified 64 dB by the pulsed amplifier chain which consists of a TWT amplifier and modulator, and a crossed field amplifier (CFA) and modulator. Minimum transmitter output power is 0.22 watt seconds for all operating modes.

(U) Both the intermediate and output waveguide sections are pressured with Freon 11C dielectric compound to prevent waveguide arcing. The modulators, CFA, and load isolator (for CFA protection) are cooled with DC-331 coolant fluid. The heat exchanger uses air flow from the aircraft source for heat removal.

(U) The transmitter is packaged for optimum maintainability and accessibility to the sub-SRA level from the WRA level. Any sub-SRA can be removed and/or replaced without disturbing any other sub-SRA. The transmitter has five SRAs, each of which contain sub-SRAs that are accessible from the SRA level when the covers are removed. Only the oil sections require removing the SRA from the transmitter for maintenance. Oil circulation around high heat dissipation com-

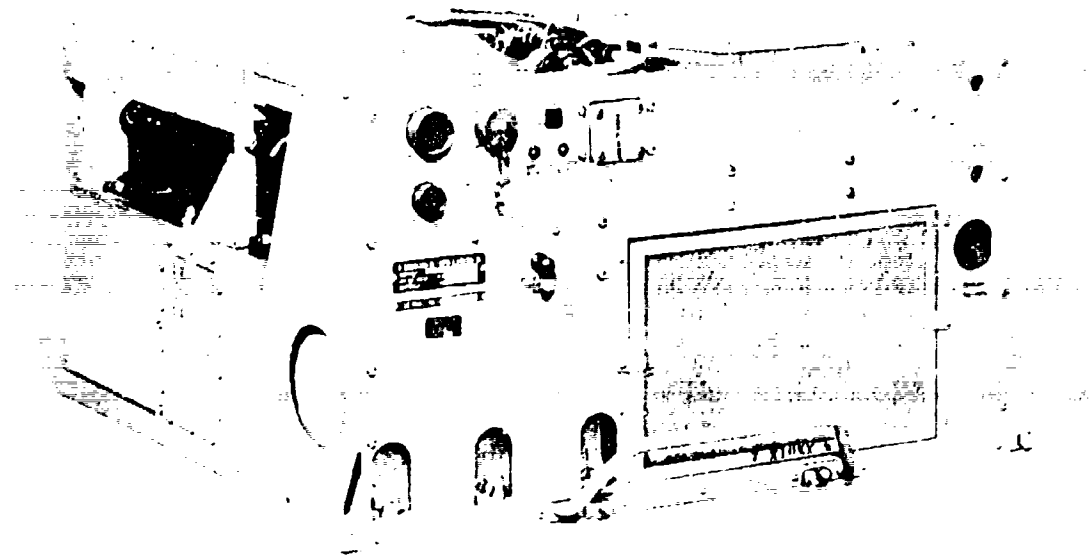

FIGURE 4. TRANSMITTER, RADAR SET T-1203(XN-3)/APS-116(XN-3)

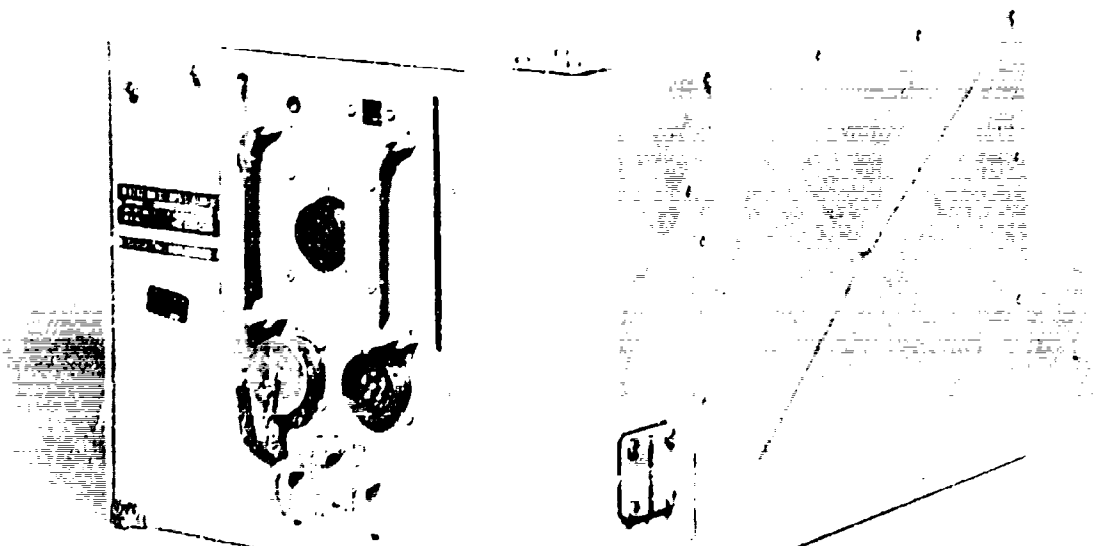

FIGURE 5. RECEIVER-PULSE COMPRESSOR R-1747(XN-3)/APS-116(XN-3)

ponents increases reliability. Cold-plate cooling of PWBs uses the oil-cooled modulator chassis for heatsinking without exposing components directly to the cooling air. The closed cycle liquid cooling system uses aircraft air to absorb heat from the heat exchanger. The cooling air is filtered with a quick replaceable filter on the transmitter front panel.

(U) All electrical circuits are plug-in modules, only the modulator high-voltage leads require soldered connections. The PWBs are low-cost throwaway sub-SRAs. The modulator oil sections are repairable sub-SRAs with test points on the SRA level. A test connector allows direct monitoring of BITE voltages on SRA and sub-SRA levels to fault-isolate from the WRA level.

(4) Receiver-Pulse Compressor R-1747(XN-3)/APS-116(XN-3)

(U) The RCVR-PC (Figure 5) operates in three modes which corresponds to the radar set operating modes. In Modes I and III the primary unit functions are selectivity; amplification; establishment of system noise figure; conversion from RF to IF frequencies; gain control to reduce dynamic range of IF; compression of the linear FM (chirp) waveform; and detection, amplification, and processing of the input video. In Mode II, pulse compression is not accomplished and instead, the signal is bandwidth limited, converted to the second IF, detected, amplified and supplied as NAV Video to the display system.

(U) The RCVR-PC is contained in a welded sheet metal package with cold walls used as integral structure members. SRAs are accessible by the removal of the top, left, or right side panels. All SRAs are attached with easily removable hardware. The unit contains two cold plates with PWBs mounted between them. Other SRAs are mounted on the outwardfacing surfaces of the cold plates. Cooling air enters the cold plates through two vertical slots in the front panel and is exhausted through a single hole on the rear panel. The PWBs are supported between the cold plates by thermally conductive card guides.

(U) All electrical plugs are located on the front panel with the FAIL and elapsed time indicators. A high power circulator is used to route in the received energy, and transfer out the RF energy from the XMTR to the antenna.

C. Qualification Tests

(1) Reliability Qualification Tests

(U) The Reliability Burn-in and Qualification Tests for the AN/APS-116(XN-3) Radar Set are discussed in the following paragraphs. The tests demonstrated that the radar exceeds the 125 hour MTBF requirement of equipment specification MIL-R-81648A(AS). The tests were performed on the four basic WRAs of pre-production systems DLZ-0009 and DLZ-0010.

(U) The four WRAs of each radar set were mounted on a vibration table inside a temperature chamber. The two radar systems were burned in and qualification tested as specified by the test procedure written in accordance with MIL-STD-781B, Test Plan IV, Level E, and approved by NASC.

(2) Burn-in Test

(U) Each of the two radars was subjected to nine hour test cycles until it was burned-in a minimum of 50 hours. Detailed system performance and built-in test equipment measurements were made during each cycle to verify proper system operation. Although burn-in failures were considered non-relevant, test logs were maintained, the failures were recorded and analyzed, and corrective action was initiated.

(3) Qualification (Demonstration) Test

(U) The two radar systems were subjected to the nine hour test cycles until an "accept" decision, as defined by MIL-STD-781B, Test Plan IV, could be reached. The accept decision for the radar was reached after 351.5 hours of relevant test time resulting in two relevant failures. The radar demonstrated a MTBF of 175 hours.

(U) a. Failure Reports - In accordance with agreements between NADC and Texas Instruments, all incidents reported during reliability burn-in and qualification testing were categorized as failures, adjustments, waivers, or other.

(U) Equipment failure reports (EFRs) were written during Reliability Burn-in and Qualification testing of radar systems DLZ-0009 and DLZ-0010. These reports were submitted to NADC in Document No. DM73-04-25, dated 23 April 1973, entitled "Reliability Qualification Test Final Report for the AN/APS-116(XN-3) Radar Set Systems 9 and 10". The following information was given for each EFR:

Test Event
EFR No.
Date
Failure Description
Applicable Test Paragraph
Corrective Action

(U) b. Relevant Failures - Two relevant failures occurred during qualification testing. The first occurred in DLZ-0009 at 29 hours of the relevant test hours for that system. The second occurred in DLZ-0010 at 66-2/3 hours of 89.6 relevant test hours, or, at 329 hours of relevant test time for both systems.

(U) c. Results - The results of the tests showed that the AN/APS-116(XN-3) radar sets tested fulfilled the qualification requirements of MIL-R-81648A(AS) with a MTBF of 175 hours.

D. Environmental Tests

(1) Temperature and Altitude Test

a. Test Conditions - The four radar WRAs were placed in the temperature/altitude chamber and subjected to temperatures ranging from -62°C to +85°C. The radar equipment was operated continuously at temperatures from -54°C to +55°C and intermittently at temperatures to +71°C. The simulated altitude ranged from sea level to 40,000 feet during radar operation.

(U) b. Test Results - Equipment failure reports were written on all equipment failures encountered during testing. The reports included a description of the cause of the failure and the corrective action taken. The corrective action was effective in all cases, therefore the radar successfully completed the temperature and altitude test.

(2) Vibration Test

(U) a. Test Conditions - The vibration test was conducted as specified by Environmental Test Procedure 718545 (Paragraph 3.7). The radar WRAs were individually vibration tested. Each was subjected to resonance search, resonance dwell, and vibration cycling tests for vibration inputs along each of three mutually perpendicular axes (x, y, z). The WRAs were hard mounted to the vibration machine for all the vibration tests.

(U) b. Test Results - One equipment failure occurred during the testing, but this failure was cleared by corrective action. The radar successfully completed vibration testing.

(3) Humidity Test

(U) a. Test Conditions - The Humidity Test was conducted as specified by Paragraph 3.7 of Test Procedure 718545. The four WRAs were installed in a humidity chamber and subjected to ten, twenty four hour test cycles. After the last cycle, the radar operation was tested. The following steps were performed for each cycle:

Raise chamber temperature to +50°C over a 2 hour period. Maintain relative humidity at greater than 95 percent.

Maintain chamber at +50°C with relative humidity greater than 95 percent for 6 hours.

Lower chamber temperature to +38°C or below over 16 hour period. Maintain relative humidity equal to or greater than 85 percent.

(U) b. Test Results - Two equipment failures were reported during the test. Both were cleared by corrective action and the radar successfully completed the Humidity Test.

(4) Explosion Test

(U) a. Test Conditions - The Explosion Test was performed as specified by Paragraph 3.9 of Test Procedure 718545. Also, to pass the explosion test, the radar had to operate in an explosive atmosphere without causing an explosion at ground level and altitudes of 5, 10, 20, 30 and 40 thousand feet.

(U) When the radar was tested in accordance with the test procedure, the combination of cooling air temperatures and flow rates prevented the chamber air/fuel mixture from being explosive. Therefore, the radar was retested with the cooling air raised to +55°C and with the air flow rates increased as necessary to prevent the WRAs from seriously overheating. The rate for each WRA remained well below the 14.8 lbs/min/kwatt maximum specified by MIL-R-81648A(AS).

(U) With these changes the radar operated without causing an explosion at each test altitude and the sample of chamber air/fuel mixture taken at each altitude exploded when ignited.

(U) b. Test Results - Since the radar operated in an explosive atmosphere in an "over test" condition caused by inadequate cooling air, Texas Instruments considers the radar to have adequately demonstrated compliance with the MIL-E-5400G requirements.

(5) Salt Spray Test

(U) The radar WRAs were sprayed with a five percent salt solution at 35°C for 48 hours in accordance with Paragraph 3.8 of Test Procedure 718545. After exposure, the units were rinsed with tap water to remove salt deposits. When the units had dried, an operational test was performed. The radar system operated as specified.

E. Electromagnetic Interference Test (EMI)

The EMI tests were performed to demonstrate the electromagnetic compatibility of the AN/APS-116(XN-3) Radar Set in accordance with the requirements of Contract N00019-70-C-0398 and specification MIL-R-81648A(AS). The tests were conducted in accordance with MIL-STD-461 and Texas Instruments procedure 711428, Revision D. The test procedure and the results of each test are detailed in Texas Instruments Document DM72-10-40, "Electromagnetic Interference Test Report for the AN/APS-116(XN-3) Radar Set" (U), dated October 1972.

Preliminary EMI testing was begun in March 1972 and an initial qualification test was performed in June 1972. Test data indicated that the radar fully met all susceptibility requirements of MIL-STD-461A, but did not meet all conducted and radiated emission requirements. Further testing was recommended and in July an extensive experimental suppression and test effort was performed that resulted in the following changes to the radar system and test equipment.

(1) Added a high [illegible]ncy filter in the transmitter A-C supply line.

(2) Eliminated 400 Hzs [illegible]und loops in the test equipment.

(3) Suppressed 8.3 MHs radiation by twisting wires in the Synchronizer-Exciter harness.

(U) (4) Stabilized an oscillating +28 VDC supply in the Power Supply.

(U) Conducted and radiated testing was then resumed. The test data showed that significant improvements resulted from the above changes.

(U) The results of the EMI test demonstrated that the AN/APS-116(XN-3) Radar passed all susceptibility tests, but exhibited out-of-specification conditions for both conducted and radiated emissions. However, because no interference problems occurred in the S-3A integration tests or in the TECHEVAL/OPEVAL tests, it was recommended that the EMI data be accepted.

F. Thermal Performance Evaluation

(U) Thermal Evaluation Tests were performed on the AN/APS-116 (XN-3) Radar Set in accordance with the requirements of MIL-T-23103. The tests determined the combination of cooling air temperatures and flow rates necessary to prevent overstress of the critical system components. In addition, the thermal time constants of the critical components were determined.

(U) The tests included:

High Temperature Evaluation - A preliminary test performed to identify the most critical component of each of the four radar units.

Steady S[illegible]s - A series of tests to determine [illegible]ry cooling air rate for each unit to ke[illegible]e most critical component below its maximum temperature for each of the temperature/altitude/coolant conditions agreed upon by NADC and TI.

Transient Tests - Tests to determine the thermal time constant of the most critical item in each unit under worst-case conditions.

Design Conditions Test - Test to determine the temperatures of the most critical items under thermal design conditions.

(U) The Thermal Performance Tests were satisfactorily completed in September 1972. For all temperature/altitude conditions the cooling air required for the radar units was within the limits specified by the equipment specification MIL-R-81648.

(U) The average part temperature, coolant heat gain, external heat transfer, and coolant utilization factors were calculated in accordance with MIL-T-12303 from thermal design conditions test data. The equipment penalty ratio was not calculated because the required aircraft cooling data was not available.

(U) After analysis of the test results, it was determined that the thermal design of the system was adequate and recommendations were made that the design be approved by NADC.

G. TECHEVAL/OPEVAL

(U) The AN/APS-116(XN-3) radar was delivered for TECHEVAL/OPEVAL flight testing on 15 August 1971 and was installed in a P-3C aircraft assigned to AIRTEVRON ONE (VX-1), Key West, Florida. The radar equipment was operated by VX-1 personnel throughout the testing period.

(1) TECHEVAL Results

(U) A project plan composed of six diversified test procedures issued by COMOPTEVFOR was used in conducting TECHEVAL tests.

(U) When TECHEVAL was completed on 20 January 1972, a total of 215 flight hours had been logged on the equipment. Only two failures that resulted in discarding of data or a mission abort occurred in the basic "4-box" AN/APS-116(XN-3) system, and they were quickly diagnosed and corrected.

(C) From the evaluation, it was concluded (refer to AEDS "Final Report of Technical Evaluation of AN/APS-116 Radar" (U)) that the test data taken during TECHEVAL show that the AN/APS-116(XN-3) performs at least as well as, if not better than, the AN/APS-116(XJ-2) tested during developmental model flights. The AN/APS-116(XN-3) will meet or exceed the minimum performance requirements of SOR 21-17.

(2) OPEVAL Results

(U) The purpose of OPEVAL was to operationally test the four major components of the AN/APS-116(XN-3) radar to determine their suitability for service use.

(U) Operational testing commenced in February 1972 and 345 hours of in-flight testing were conducted. An additional 169.5 hours of operating time accumulated during technical testing brought the total operating time to 514.5 hours. This total operating time was considered valid for purposes of determining material suitability.

(U) No failures occurred in either the Synchronizer-Exciter or Receiver-Pulse Compressor. One failure occurred in the Power Supply and two failures occurred in the Transmitter. Overall MTBF for the four components was 171.5 hours. No significant discrepancies were noted in the areas of compatibility, maintainability, technical documentation, or human factors.

(U) The test data indicated that the four components of the AN/APS-116(XN-3) radar met or exceeded operational acceptance criteria and met material suitability criteria with results consistent with SOR 21-17. In addition, the test bed installation of the radar used in this evaluation exceeds the AN/APS-115 radar in overall operational performance.

(U) It was recommended that the components of the AN/APS-116(XN-3) radar that were tested be accepted for Service use.

H. AN/APS-116(XN-3) Radar Deliveries

(U) The ten systems procured under this contract were delivered as follows:

| Serial No. | Date Delivered |
|---|---|
| DLZ-0001 | 2 Apr 1971 |
| DLZ-0002 | 2 Jun 1971 |
| DLZ-0003 | 16 Aug 1971 |
| DLZ-0004 | 27 Oct 1971 |
| DLZ-0005 | 11 Nov 1971 |
| DLZ-0006 | 28 Dec 1971 |
| DLZ-0007 | 26 Jan 1972 |
| DLZ-0008 | 17 Mar 1972 |
| DLZ-0009 | 24 Mar 1972 |
| DLZ-0010 | 24 Apr 1972 |

## IV. CONCLUSIONS

The AN/APS-116(XN-3) Radar was successfully designed, built and tested by Texas Instruments in accordance with the designated specifications and the last unit was delivered to the Navy on 24 April 1972.

During qualification testing the radar met or exceeded the requirements of the design specifications. The failure rate during testing was minimal and the corrective action employed cleared all failures. Analysis of the Thermal Performance Evaluation determined that the thermal design was adequate for all conditions.

It was concluded that the AN/APS-116(XN-3) demonstrated improved performance and reliability and exceeds the AN/APS-115 radar in overall operational performance.